3.3.5 Landslide

The term *landslide*, as used here, includes all types of gravity-caused mass movements of earth material, ranging from rock falls, slumps, rock slides, mud slides, and debris flows. Landslides occur in all 50 of the United States (USGS, 2001).

3.3.5.1 Background

- The surface of the Earth is a collection of slopes that are inherently unstable. When material is exposed at the Earth's surface, weathering and erosional processes immediately begin to break it apart and move it.
- Earth movement may occur suddenly as catastrophic landslides or rockfalls, but more commonly, occurs almost imperceptibly as the slow creep of soil down gentle slopes.
- Precipitation, topography, geology, and human activities can all trigger landslides.
- In landslide-prone areas, anything affecting slope condition, such as construction, seismic activity, or increased soil moisture, may cause movement or may reactivate prior movement.
- Recent landslide movements often are the reactivation of smaller sections of older, unstable landslide masses.
- Slope failures are often triggered by human activities, including mining and construction of highways, buildings and railroads.
- Landslides can damage and destroy homes, roads, railroads, pipelines, electrical and telephone lines, mines, oil wells, commercial buildings, canals, sewers, bridges, dams, airports, forests, parks, and farms.
- According to FEMA (1997), best estimates of losses attributed to landslides in the United States are 25 to 50 lives per year and \$1-2 billion in property damage.

Sources: USGS, 2004; MBMG, 2002

3.3.5.2 History of Landslides in Montana

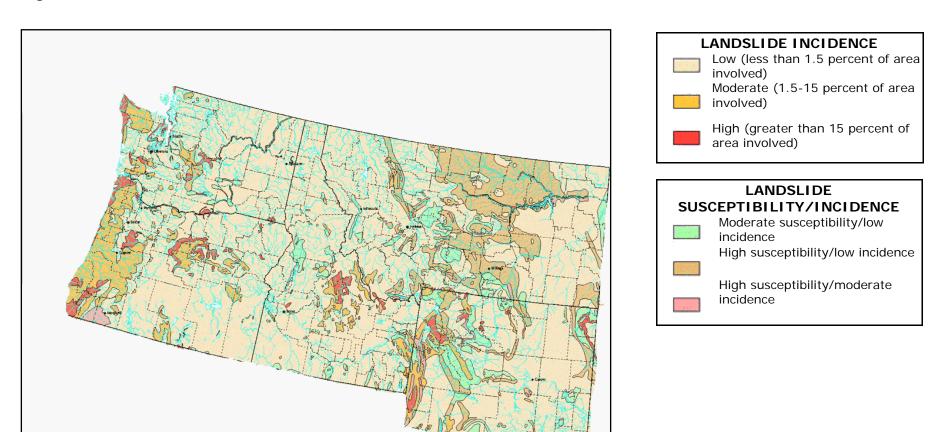
Landslides are among the most common geologic hazards in Montana, causing damage in rural and urban areas of the state. Sudden movements are often spectacular and receive



The much publicity. Hebgen Earthquake of August 18, 1959 triggered the largest landslide in Montana history, where nearly 1.25 miles (2 km) of the Madison River and Montana Highway 287 were buried to depths as great as 394 feet (120 m) (see Section 3.3.2.2, History of Earthquakes). However, slower movement also cause severe problems in developing areas. The effects of the very slow (imperceptible) movements can be seen along many Montana roadways in the form of leaning trees, misaligned fences and walls, and damaged road surfaces and foundations (MBMG, 2002).

Photo 3.5.2-1 Landslide from Hebgen Lake Earthquake, August 1959

Figure 3.3.5-1 Landslide Areas in the Northwest United States



Note: Susceptibility not indicated where same or lower than incidence. Susceptibility to landslide was defined as the probable degree of response of the areal rocks and soils to natural or artificial cutting or loading of slopes, or to anomalously high precipitation. High, moderate, and low susceptibility are delimited by the same percentages used in classifying the incidence of landslide. Some generalization was necessary at this scale, and several small areas of high incidence and susceptibility were slightly exaggerated

Source: Godt, 1997

Whether caused solely by natural processes or aggravated by human activity, when landslides occur in proximity to human-made structures, repairs and remediation can be



costly. For example, a small lobe of a much larger ancient slide south of Dillon was reactivated by removing the toe of the slope. The slide is proving very costly to the railroad and could impact Interstate 15 if a larger segment of the slide area should move (MBMG, 2002). State Highway 2 was built on another slide near Glacier Park and the roadway has had constant subsidence problems. The Goat Lick slide forced the Montana Department of Transportation (MDT) to re-construct the roadway with a cantilevered outside driving lane prevent further to subsidence.

Photo 3.5.2-2 Goat Lick Slide, US Highway 2

A rain-on-snow event in mid-March 2005 caused a mudslide that severely damaged more than 12 miles of U.S. Highway 212 outside Red Lodge, Montana. The road is a crucial link to the western route to Yellowstone Park and is only open to traffic from late-May until mid-



October. An Executive Order was issued declaring an emergency in Carbon County. The order requested assistance from the Federal Highway Administration for the repairs. The \$15.2 million repair involved excavating rock and slide debris, reconstructing the drainage, roadway and new alignment, constructing tie-back walls. Rock fall fences were also constructed at several locations and overall drainage capacity creating was increased by diversions along stable locations on the mountain and constructing special inlets to allow rock over 3-inch diameter to pass.

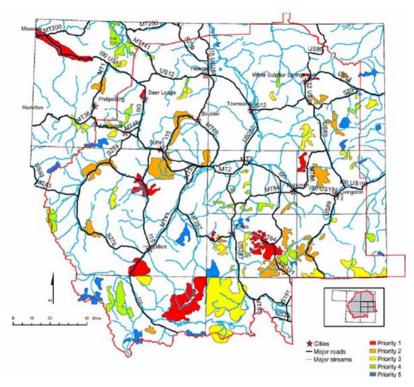
Photo 3.5.2-3 Beartooth Highway Landslide

In Montana, or the nation for that matter, a readily available inventory of landslides and their impacts does not exist. The Montana Bureau of Mines and Geology (MBMG) initially began a statewide compilation of landslide information as part of a hazard assessment project in 1985 and 1986 in cooperation with the U.S. Geological Survey. However, the project was left incomplete and the data unpublished because federal funding for the hazard-assessment program was discontinued. MBMG and MDT did complete an inventory of landslides in the southwestern portion of Montana (MBMG, 2002); however, this inventory identifies priority areas based upon the susceptibility to landslides near state highways. MBMG mapped 4,640 landslides within MDT's District 2, which were categorized as earth landslides (1,922 or 41.5 percent), debris landslides (2,556 or 55 percent), and rock landslides (162 or 3.5 percent). The most important movement types identified were

slides (2,759 or 59.5 percent), followed by flows (1,813 or 39 percent), and composite or compound movement types (54 or 1.2 percent).

MBMG (2002) assigned a priority rating to each area containing clusters or large numbers of landslides (**Figure 3.3.5-2**). They determined that all of District 2 has clustered landslide areas, however, the Ennis 1:100,000-scale quadrangle area is considered overall to have the highest priority.

Figure 3.3.5-2 Priority Landslide Areas in MDT District 2 Source: MBMG, 2002



Landslides appear to have a stronger association with faulting than with any specific geologic unit (MBMG, 2002); however, some geologic formations or lithologies could be identified as being particularly prone to movement:

- Volcanic rocks, or sediments derived from them, are often the originating lithology for landslides. These sediments often contain ash and clay materials that facilitate movement.
- Poorly-consolidated sediments, particularly those of Cretaceous, Tertiary and Quaternary age, appear to have a tendency toward landslide.
- In the Butte and Dillon 1:250,000-scale areas, Proterozoic-age (Precambrian Belt Supergroup) rocks appear to be prone to landslide.

The types of material identified for each slide or flow appears to generally correspond to well-defined topographic settings:

- Earth slides and flows occur most often on more gentle slopes with less vegetation—the foothills and river courses.
- Debris slides and flows generally occur in the steeper, mountainous areas and in areas covered with vegetation.

 Rock slides and flows occur in previously-glaciated high valleys with steep slopes that generally lack vegetative cover, and along other very steep slopes (generally greater than 50 degrees).

3.3.5.3 Declared Disasters from Landslides

One disaster declaration due to a landslide has occurred in Montana. Executive Order No. 08-05, proclaiming an emergency to exist in Carbon County was signed by the governor on May 27, 2005 (MDES, 2007). Flooding and rapid runoff caused landslides at several locations on U.S. Highway 212 (Beartooth Highway) to result in serious and extensive damage to both public and private property, including a federal-aid highway. The Federal Highway Administration reimbursed Montana \$15 million for expenses associated with the highway repair as part of an emergency supplemental appropriations package passed by Congress and signed by President Bush. The Small Business Administration made a declaration to provide assistance to small, non-farm businesses in Big Horn, Carbon, Gallatin, Golden Valley, Meagher, Park, Stillwater, Sweet Grass, and Yellowstone Counties that suffered financial losses as a result of the closure of the Beartooth Highway due to the landslide disaster (SBA Declaration #10130) (US SBA, 2007).

3.3.5.4 Vulnerability to Landslides

3.3.5.4.1 Statewide Vulnerability to Landslides

Vulnerability to landslides is dependent on slope, lithology, and location of current and ancient slides. Activation of landslides depends upon environmental factors, such as amount of rainfall and snowmelt, and human activities, such as road and housing construction.

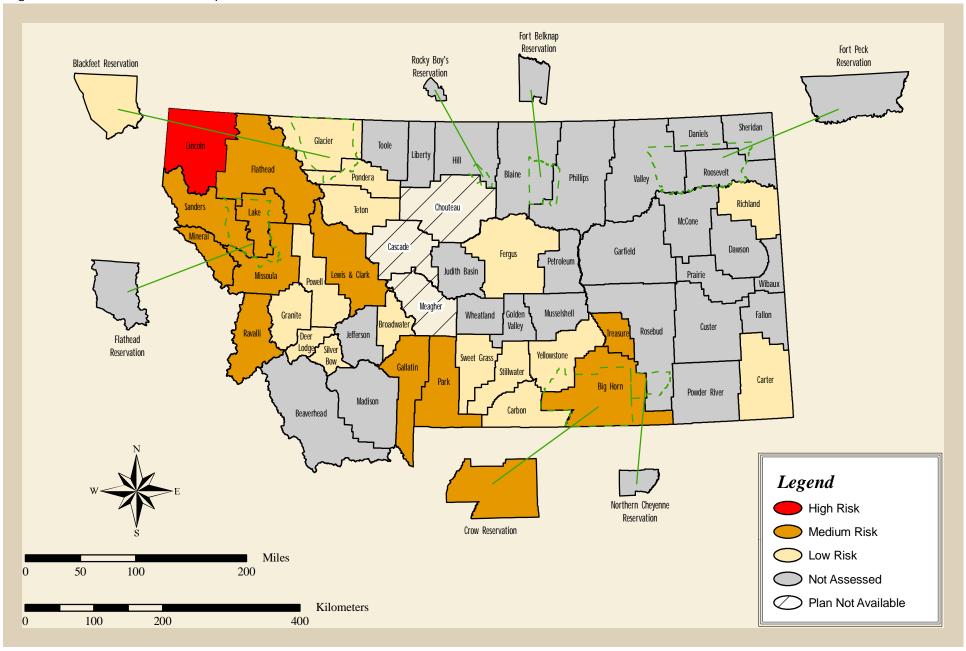
A comprehensive map of existing slide areas throughout the state would greatly improve the capability to prevent development in ancient slides areas, however, many landslides cannot be predicted and can be activated by multiple factors including earthquakes, high precipitation, overgrazing, and deforestation (especially from forest fires). Many, if not most, high-risk areas can be identified on the basis of past landslide activity. Many recent landslides are small, relatively minor events within the boundaries of older, much larger ones. Recognition of the larger framework, as well as mapping current landslide locations, is paramount to understanding the problem.

3.3.5.4.2 Review of Potential Losses in Local PDM Plans

Figure 3.3.5-3 presents the Landslide Hazard Risk Map. The colors represent a high-medium-low risk rating based on information in the Local PDM Plans. The gray color indicates this hazard was not assessed in the Local Plan. The hatch pattern indicates the Local Plans were not available for review. For electronic users of the State Plan, clicking on a county or tribal reservation will take you to the Local Plan where further information is available.

Table 3.3.5-1 presents a summary of potential loss estimates due to landslides as calculated in the Local PDM Plans. Landslide loss is described in terms of its effect on buildings, society and the economy, where generally:

Figure 3.3.5-3 Hazard Risk Map: Landslide



- Building loss is presented either as a dollar value or a high-moderate-low rating and typically refers to the potential loss to critical facilities in the jurisdiction.
- Societal loss is presented either as the number of lives at risk or as a high-moderate-low rating representing the potential for loss of human life.
- Economic risk is presented as a dollar value or high-moderate-low rating referring to the potential impact to the economy of the local jurisdiction.

References cited in **Table 3.3.5-1** correspond to a description of the method used to calculate potential loss that can be found in *Section 7.14*.

Table 3.3.5-1 Potential Losses from Local Plans: Landslides

DES District	Jurisdiction	Building Loss	Societal Loss	Economic Loss	Reference
1	Deer Lodge County	Low	Low	Low	1
1	Flathead County	Low	Low	Low	8
1	Flathead Reservation	NA	NA	NA	
1	Granite County	NA	NA	NA	
1	Lake County	NA	NA	NA	
1	Lincoln County	1	1	NA	9
1	Mineral County	\$500,000-\$1	Low	NA	10
1	Missoula County	million \$500,000-\$1	Low	NA	10
'	Wissoula County	#300,000-\$1	LOW	INA	10
1	Powell County	Low	Low	NA	10
1	Ravalli County	\$500,000-\$1	Low	NA	10
1	Sanders County	million NA	NA	NA	
1	Silver Bow County	Low	Low	Low	1
	,				'
2	Blackfeet Reservation	NA	NA	NA	
2	Blaine County	NA	NA	NA	
2	Cascade County	U	U	U	
2	Chouteau County	U	U	U	
2	Fort Belknap Reservation	NA	NA	NA	
2	Glacier County	NA	NA	NA	
2	Hill County	NA	NA	NA	
2	Liberty County	NA	NA	NA	
2	Pondera County	NA	NA	NA	
2	Rocky Boy's Reservation	NA	NA	NA	
2	Teton County	NA	NA	NA	
2	Toole County	NA	NA	NA	
3	Beaverhead County	NA	NA	NA	
3	Broadwater County	Low	Low	Low	1
3	Gallatin County	Low	Low	Low	12
3	Jefferson County	NA	NA	NA	
3	Lewis & Clark County	NA	NA	NA	
3	Madison County	NA	NA	NA	
3	Meagher County	U	U	U	
3	Park County	Low	Low	Low	1
3	Sweet Grass County	NA	NA	NA	
4	Carter County	Low	Low	Low	12
4	Custer County	NA	NA	NA	

Table 3.3.5-1 Potential Losses from Local Plans: Landslides

DES District	Jurisdiction	Building Loss	Societal Loss	Economic Loss	Reference
4	Dawson County	NA	NA	NA	
4	Fallon County	NA	NA	NA	
4	Garfield County	NA	NA	NA	
4	McCone County	NA	NA	NA	
4	Powder River County	NA	NA	NA	
4	Prairie County	NA	NA	NA	
4	Richland County	Low	Low	Low	3
4	Wibaux County	NA	NA	NA	
5	Big Horn County	\$390,000	Low	Severe	3
5	Carbon County	\$20,000,000	NA	High	8
5	Crow Reservation	Hundreds of thousands	Moderate	Moderate	3
5	Golden Valley County	NA	NA	NA	
5	Musselshell County	NA	NA	NA	
5	Northern Cheyenne Reservation	NA	NA	NA	
5	Rosebud County	NA	NA	NA	
5	Stillwater County	NA	NA	NA	
5	Treasure County	Moderate	Moderate	Moderate	1
5	Wheatland County	NA	NA	NA	
5	Yellowstone County	NA	NA	NA	
6	Daniels County	NA	NA	NA	
6	Fergus County	NA	NA	NA	
6	Fort Peck Reservation	NA	NA	NA	
6	Judith Basin County	NA	NA	NA	
6	Petroleum County	NA	NA	NA	
6	Phillips County	NA	NA	NA	
6	Roosevelt County	NA	NA	NA	
6	Sheridan County	NA	NA	NA	
6	Valley County	NA	NA	NA	

Notes: U = Local PDM Plan not available for review; NA = not assessed in Local PDM Plan

Potential loss was computed was not computed in a uniform manner in Local PDM Plans. See number references in

Section 7.14 for a description of the methods used to determine potential building, societal, and economic loss.

3.3.5.4.3 Vulnerability of State Property

The ability to assess losses to state-owned buildings and infrastructure are dependent on the ability to map hazard areas and the ability to locate these structure and infrastructures within those zones. Montana does not have comprehensive and reliable landslide incidence mapping completed statewide and the state buildings cannot be geo-referenced. A second approach is to review historic losses and project those losses into the future. Over the past ten years, no insurance claims related to landslide damage have been made for state-owned buildings.

The greatest exposure to state infrastructure may be to roadways. Two of the major slides, the Pipe Organ slide on Interstate 15 and the Goat Lick slide on Highway 2, were discussed previously. Both slides that bury public roads, and those that undermine them, represent significant costs to the state. Although historically, damages to public roads from landslides

have occurred, the Montana Department of Transportation does not maintain a compilation of losses and repairs to roadways as a result of landslides.

The potential losses from landslides to state buildings and infrastructure cannot be estimated quantitatively without detailed mapping. Qualitatively, however, without past disaster declarations from landslides, the impact can be considered low.

3.3.5.5 Impact of Future Development

As urbanization and development increase in Montana, particularly in the mountainous regions, the potential for large losses from landslides also increases. Landslide risk should be evaluated on a case-by-case basis to reduce or eliminate exposure of public infrastructure and private development.

3.3.5.6 Landslide Data Limitations

The major data limitation regarding landslides is the lack of statewide information on existing landslides and landslide-prone areas. The USDA Forest Service has mapped landslide areas on individual National Forests, but this information is not digitally available.

Limitations to State Building Evaluations

To effectively determine vulnerability of State property, data identifying locations of State buildings is necessary. The current PCIIS building database is not geo-referenced and cannot be effectively related to spatial coordinates except in general locations (by city or zip code centroid).

Limitations to MBMG (2002) Study of MDT Region 2

Any use made of the MBMG (2002) data regarding MDT Region 2 should consider the methods of collection and interpretation, and the scale at which the initial data were gathered:

- The original compilation of data was done at 1:250,000 scale; therefore, if the data are used at a larger scale, inaccuracies could occur in both location and shape.
- Locations were originally gathered using several methods: aerial-photo interpretation, literature references, aerial reconnaissance, and field mapping.
- Locations were checked by either fieldwork or aerial reconnaissance, but detailed mapping was not done in either case.
- Data have been provided by several investigators and at various scales, therefore inconsistency in definitions, recognition of types, and locations may exist. More detailed studies in specific areas may require corrections and/or additions to the database.
- The information, location, references, and definitions in the database and in this report are as complete as feasible at this time, but must be considered as products that will continue to evolve as new or improved data become available.
- The accuracy of the landslides located from aerial photographs varies according to date, quality, and scale of the photographs.

3.3.5.7 Landslide References

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